

**American College of Radiology  
ACR Appropriateness Criteria®**

**Clinical Condition:** Suspected Upper Extremity Deep Vein Thrombosis

<b>Radiologic Procedure</b>	<b>Rating</b>	<b>Comments</b>	<b><u>RRL*</u></b>
US upper extremity(ies) with Doppler	9	Standard for arm veins. Other modalities are required for evaluating central veins.	O
X-ray chest	8	Simple, low-cost evaluation of lines, mediastinal contours, and cervical ribs.	☢
MRA (venography) chest (noncoronary) without and with contrast	7	Asymptomatic side injection is preferred. For central veins. See statement regarding contrast in text under “Anticipated Exceptions.”	O
MRA (venography) chest (noncoronary) without contrast	7	Can be performed when contrast is contraindicated.	O
X-ray venography upper extremity(ies) and SVC	7	Although this is the gold standard, it generally reserved for inconclusive noninvasive studies.	☢ ☢ ☢
CTA (venography) chest (noncoronary) with contrast	7	Asymptomatic side injection is preferred. Alternative to MR venography for central veins.	☢ ☢ ☢ ☢
Radionuclide venography upper extremity(ies) and chest	3	Largely supplanted. Limited use for central veins when CT and MR venography are both contraindicated.	☢ ☢ ☢
<b>Rating Scale:</b> 1,2,3 Usually not appropriate; 4,5,6 May be appropriate; 7,8,9 Usually appropriate			<b>*Relative Radiation Level</b>

# SUSPECTED UPPER EXTREMITY DEEP VEIN THROMBOSIS

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## **Summary of Literature Review**

### **Introduction/Background**

Upper-extremity venous thrombosis often presents as unilateral arm swelling. The differential diagnosis includes a mass lesion or other lesion compressing the veins and causing a functional venous obstruction, venous stenosis, or an infection causing edema [1]. Bilateral upper-extremity swelling may also be due to right-sided heart failure, although this is typically associated with generalized swelling, in contrast to central vein obstruction, which can cause swelling limited to the upper extremity and face [1].

Obstruction of previously functioning lymphatic's or the absence of sufficient lymphatic channels to ensure effective drainage may also cause arm swelling. Lymphatic obstruction can be seen with infection such as cellulitis or can be secondary to invasion of the lymphatics by tumor. Absence of the lymphatics can be congenital or secondary to surgery, such as following a radical mastectomy [2].

The following recommendations are made with the understanding that venous disease, specifically venous thrombosis, is the primary diagnosis to be excluded or confirmed in a patient presenting with unilateral upper-extremity swelling.

### **Upper-Extremity Deep Vein Thrombosis**

Upper-extremity deep vein thrombosis (DVT) can be associated with indwelling catheters [3-7], be idiopathic

or posttraumatic [5,8], or be secondary to extrinsic compression syndrome ("effort thrombosis" or Paget-Schrötter disease) [5,9].

Upper-extremity DVT is commonly associated with the presence of indwelling central venous catheters [3,6,7,10-12]. The presence of the catheter, a foreign body, increases the likelihood of venous thrombosis by altering flow [1], causing damage to the endothelial lining of the vein, and serving as a site for platelet adherence [1]. The increased use of chronically indwelling catheters for hemodialysis, chemotherapy, or parenteral nutrition, often in a population that already has additional risk factors for venous thrombosis, has increased the incidence of upper-extremity DVT. As is the case with lower-extremity DVT, the likelihood of upper-extremity DVT increases with the presence of risk factors such as age, previous thrombophlebitis, postoperative state, hypercoagulability [3,4,8], heart failure [3], cancer [4-8,11,13], right heart procedures, and ICU admissions [7].

The location of the venous thrombosis is strongly linked to the clinical presentation. For example, head, neck, or bilateral upper-extremity swelling suggests a central process in the mediastinum [1] involving the superior vena cava or both subclavian and brachiocephalic systems [14]. Superficial thrombophlebitis is associated with local pain, induration, and, often, a palpable cord. It is rarely, if ever, associated with diffuse arm swelling [15]. Unilateral swelling indicates an obstructive process at the level of the brachiocephalic, subclavian, or axillary veins [14,15]. DVT limited to the brachial veins need not be associated with swelling. Isolated jugular vein thrombosis is asymptomatic and rarely causes swelling. There may be a correlation between upper-extremity and lower-extremity DVT, and investigation of the lower extremities as well should be considered if an upper-extremity thrombus is found in the absence of a local cause [16].

### **Differentiating Causes of Upper-Extremity Swelling**

The initial approach to a patient who presents with a swollen upper extremity is exclusion of venous thrombosis, because anticoagulation is typically required and the underlying lesion may require a more aggressive intervention such as thrombolysis. Once the diagnosis of DVT is excluded, other etiologies may need to be evaluated. Combination of clinical features alone can be used to design a clinical prediction score for diagnosing upper-extremity DVT [17]. Blood tests can also be used to detect the presence of DVT. Plasma D-dimer is a degradation product of cross-linked fibrin that is elevated during thromboembolic events. The blood evaluation for plasma D-dimer in patients with suspected upper-extremity DVT is highly sensitive but not very specific [18]. It is also unreliable to diagnose recurrent DVT or alternative conditions that mimic DVT, and is unable to assess the location and extent of the venous thrombus, which is critical for proper therapeutic management of DVT [19].

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Imaging is often required for definite exclusion of DVT and to document its location and extent. Different imaging techniques that can be used to achieve the diagnosis include noninvasive tests such as radionuclide venography, ultrasound (US), magnetic resonance imaging (MRI), computed tomography (CT), and finally venography. Other techniques, such as photoplethysmography, might also prove useful [20].

### **Chest Radiography**

Because of the broad differential diagnoses of upper-extremity swelling, a chest radiograph may identify a mass lesion responsible for central venous obstruction or help confirm the presence and location of wires, catheters, or a retained wire or catheter fragment. Rare osseous entities that might be associated with extrinsic compression syndromes, such as a cervical rib, would also be detected.

### **Radionuclide Imaging, Flow Studies**

Radionuclide studies can confirm upper-extremity venous obstruction. The diagnostic criteria include failure to visualize one or more of the main venous segments (axillary, subclavian, brachiocephalic, or superior vena cava) and visualization of collateral venous channels. This test is typically not able to differentiate intrinsic venous thrombosis from extrinsic compression [2,21-23].

### **X-ray Venography**

This is the “reference standard” [24] examination for evaluating the upper-extremity veins. The examination carries the risks associated with the injection of an iodinated contrast agent [24,25]. Patient tolerance has been improved, and the risks of adverse events have been reduced with low-osmolar contrast agents. Direct evidence of venous thrombus is based on the visualization of a filling defect in the vein. Less specific findings for venous thrombus include abrupt contrast cut-off, absence of contrast filling, or the presence of collateral channels [26]. Venography can identify fixed venous stenoses and, with upper-extremity maneuvers (abduction), can identify extrinsic venous compression. Asymptomatic or minimally symptomatic venous compression with arm abduction should be treated with caution, as this finding can be made in a substantial number of normal individuals. Venography can also identify recurrent acute venous thrombus in patients with prior history of venous thrombus. Despite its widespread acceptance as a reference standard based on extension of evidence associated with lower-extremity DVT, there are few clinical trials supporting its use.

### **Venous Ultrasound**

This relatively inexpensive test can exclude DVT and help identify a proximal venous obstruction. It is noninvasive, can be performed at the patient’s bedside, and can be used for serial evaluation. Diagnostic criteria for direct evidence of thrombus, as in the lower extremity, include loss of compression of imaged vein walls when pressure is applied on the skin during real-time imaging, and visualization of echogenic material in the vein.

Indirect evidence of thrombus includes altered blood flow patterns [8,25-29]. Loss of compressibility is consistent with acute DVT but can also occur in the presence of chronic venous thrombosis [8,26]. This can be used for peripheral veins such as jugular, axillary, basilic, cephalic, and brachial veins. Compression cannot be used to evaluate subclavian or more central veins, as bony structures prevent visualization and/or compression of the veins.

A full examination also includes evaluation of the Doppler velocity profiles obtained from blood in the major veins and color-flow Doppler imaging. Reduction in Doppler velocity changes due to cardiac pulsatility are reliable indicators of central venous obstruction [12,29,30]. In addition, respiratory maneuvers such as rapid inspiration or “sniffing” should cause the walls of the subclavian veins to collapse [24,30,31]. Impairment of this collapse (which is related to rapid venous emptying) also indicates a central obstructive process [10,29,30]. However, a central thrombus will cause the same alterations in blood flow as a mass encasing or compressing the central (superior vena cava, brachiocephalic) veins or a benign stricture. Color flow imaging can be used to image the presence or absence of flow within the vein and is useful in evaluating venous segments where compression maneuvers cannot be applied (eg, to the central subclavian vein) [8,10,30], although a study has suggested that if *only* blood flow abnormalities are seen, conventional venography may be necessary [8].

Gray-scale imaging can be used to identify echogenic thrombus. However, acute hypoechoic thrombi may be missed using gray-scale imaging alone. Adjunctive use of color flow images can help in confirming the presence or absence of hypoechoic thrombus, and can also help determine if a clot is obstructive or partially obstructive. Correlative studies between US and venography show diagnostic sensitivities and specificities above 80% [5,8,10,12,24-26,29,31-33].

### **Magnetic Resonance Imaging**

Approaches to venous imaging using MRI include black-blood and flow-based or contrast-enhanced bright-blood techniques [34]. *Black-blood* techniques include conventional T1 or T2 spin-echo [28,35] or fast spin-echo imaging. However, the black-blood effect on routine spin-echo imaging may not be consistent, and newer double inversion-recovery techniques provide more reliable black-blood imaging [34]. Using black-blood imaging, the presence of thrombus is inferred from focal high signal, often with enlargement, of the involved vein, but it must be differentiated from a variety of flow artifacts [35]. The high signal in thrombus on T1 imaging decreases after 6 months, and the technique is less useful for chronic thrombus [36].

*Flow-based* bright-blood MR venography (MRV) techniques include time-of-flight (TOF) [34,37,38] and phase contrast [34,35]. For venous imaging, TOF is limited to a 2D implementation due to signal saturation of

slow flow [39]. Vessels with primarily in-plane flow are more difficult to image due to saturation [39]; 2D TOF is thus most useful in the axial plane to image flow in the jugular veins, right brachiocephalic vein, and superior vena cava (SVC) which are oriented primarily in the superior-inferior direction. TOF venography can be used to image the subclavian vein, but more time-consuming sagittal acquisitions are preferred due to the direction of flow, and breathing artifacts may also impair imaging quality [4,39,40]. Phase contrast has not been widely used for upper-extremity venography due to the slow flows that must be detected [39]. Recently, balanced gradient echo (steady-state free precession) and cardiac-gated 3D fast spin-echo techniques have been implemented for noncontrast MR vessel imaging. While these techniques have not been evaluated for chest venography, they appear promising [39,41,42]. Balanced gradient-echo images alone are insensitive for detecting central venous thrombus [43], partly because of the variable signal intensity of thrombus over time, as acute thrombus is relatively isointense to blood with such sequence. Cardiac-gated 3D fast spin-echo techniques can help differentiate transient flow artifacts from true filling defects that persist over the cardiac cycle.

*Contrast-enhanced* MRV [37,44,45] can also be used by implementing 2D or 3D T1 gradient-echo images with fat saturation after administration of a single or a double dose of MR contrast [39]. Typically, venous imaging is carried out after an MR arteriogram by simply imaging out into the venous or equilibrium phases of contrast distribution [34,39]. Fibrin-specific MR contrast agents have also been developed that can further enhance all thrombi and even detect thrombi not readily visible in precontrast imaging [46]. New time-resolved imaging allows visualization of flow dynamics and may decrease required contrast volume and acquisition time and improve specificity [47]. It has found use in protocols for whole-body venography [48], and was shown to produce images of comparable diagnostic quality but lower specificity compared to conventional MRV [49] in the assessment of central thoracic veins. It might eventually be used to safely image patients with poor renal function, but further study is required.

The advantages of MRV are primarily for central venous evaluation, as the central veins cannot be imaged directly by US. For imaging the arm itself, US or even x-ray venography is preferred. MRV of the arm is rendered more difficult by its placement at the periphery of the magnetic field or the requirement to maintain the arm motionless over the head. MRI has a strong ability to delineate extravascular anatomy. It can be used to identify alternative diagnoses that mimic DVT and identify sources of extrinsic venous compression that may be an underlying cause for DVT. So MRV protocols often include standard MRI sequences such as T1W (spin echo, gradient return echo [GRE]) and T2W (fast spin echo) sequences to assess the anatomy surrounding the vessels. Studies so far specifically comparing MRV to venography have been mixed, with some work showing MRV to be as

effective as venography [38,45], but other work showing its limitations [28,35,37]. A recent meta-analysis found MRV to have both a high sensitivity and a high specificity [50], although the study was not focusing on the upper extremities.

### Computed Tomography

CT can be used to determine the presence of centrally located thrombi or stenoses within the jugular veins [51,52], the brachiocephalic veins [53,54], and the superior vena cava [53]. The presence of an extrinsic process causing venous obstruction of the venous channels can also be determined [55]. CT is the main imaging modality for staging neoplastic involvement in the mediastinum and axillae, which can include vascular invasion or compression. Perivascular inflammatory changes around chronic thrombi can also be detected by CT [56]. Delayed imaging at 90 to 120 seconds can permit evaluation of the central veins. It is important to administer large doses of contrast (up to 150 cc) in order to ensure adequate venous opacification. New techniques involving dual injections of contrast have been developed for CT venography and look promising [57]. No large series have looked at the diagnostic accuracy of this technique for diagnosing upper-extremity venous thrombosis, although extensive experience is accumulating with lower-extremity venous thrombosis. One small series show that the performance of CT venography is similarly to that of conventional venography in the thoracic and upper-extremity veins, and that it evaluates the central extent of obstruction more effectively [55].

### Summary

- Despite the availability of noninvasive imaging techniques, contrast venography remains the best reference standard diagnostic test for suspected upper-extremity acute venous thrombosis.
- Contrast venography may be needed whenever other noninvasive strategies fail to adequately image the upper-extremity veins. Additionally, as venography is the first step in direct catheter-based thrombolysis, in situations such as acute upper-extremity DVT where the likelihood of percutaneous thrombectomy or thrombolysis is high, it is sensible to proceed directly to venography.
- Duplex, color flow, and compression US have also established a clear role in evaluation of the more peripheral veins that are accessible to sonography.
- Gadolinium contrast-enhanced MRI is routinely used to evaluate the status of the central veins. Unfortunately, despite its widespread clinical use, there are few validation studies of this technique compared to the extensive literature on contrast venography. The recognition of gadolinium as a cause of nephrogenic systemic fibrosis has increased interest in noncontrast MR venography, but validation of these techniques in the chest remains an issue.

- Delayed CT venography can often be used to confirm or exclude more central vein venous thrombi, although substantial contrast loads are required. As in the case of MR venography, there are few correlative studies justifying this approach.

### Anticipated Exceptions

Nephrogenic systemic fibrosis (NSF) is a disorder with a scleroderma-like presentation and a spectrum of manifestations that can range from limited clinical sequelae to fatality. It appears to be related to both underlying severe renal dysfunction and the administration of gadolinium-based contrast agents. It has occurred primarily in patients on dialysis, rarely in patients with very limited glomerular filtration rate (GFR) (ie, <30 mL/min/1.73m<sup>2</sup>), and almost never in other patients. There is growing literature regarding NSF. Although some controversy and lack of clarity remain, there is a consensus that it is advisable to avoid all gadolinium-based contrast agents in dialysis-dependent patients unless the possible benefits clearly outweigh the risk, and to limit the type and amount in patients with estimated GFR rates <30 mL/min/1.73m<sup>2</sup>. For more information, please see the [ACR Manual on Contrast Media](#) [58].

### Relative Radiation Level Information

Potential adverse health effects associated with radiation exposure are an important factor to consider when selecting the appropriate imaging procedure. Because there is a wide range of radiation exposures associated with different diagnostic procedures, a relative radiation level (RRL) indication has been included for each imaging examination. The RRLs are based on effective dose, which is a radiation dose quantity that is used to estimate population total radiation risk associated with an imaging procedure. Patients in the pediatric age group are at inherently higher risk from exposure, both because of organ sensitivity and longer life expectancy (relevant to the long latency that appears to accompany radiation exposure). For these reasons, the RRL dose estimate ranges for pediatric examinations are lower as compared to those specified for adults (see Table below). Additional information regarding radiation dose assessment for imaging examinations can be found in the ACR Appropriateness Criteria<sup>®</sup> [Radiation Dose Assessment Introduction](#) document.

Relative Radiation Level Designations		
Relative Radiation Level*	Adult Effective Dose Estimate Range	Pediatric Effective Dose Estimate Range
O	0 mSv	0 mSv
☼	<0.1 mSv	<0.03 mSv
☼ ☼	0.1-1 mSv	0.03-0.3 mSv
☼ ☼ ☼	1-10 mSv	0.3-3 mSv
☼ ☼ ☼ ☼	10-30 mSv	3-10 mSv
☼ ☼ ☼ ☼ ☼	30-100 mSv	10-30 mSv

\*RRL assignments for some of the examinations cannot be made, because the actual patient doses in these procedures vary as a function of a number of factors (eg, region of the body exposed to ionizing radiation, the imaging guidance that is used). The RRLs for these examinations are designated as NS (not specified).

### Supporting Document(s)

- [ACR Appropriateness Criteria<sup>®</sup> Overview](#)
- [Procedure Information](#)
- [Evidence Table](#)

### References

1. Joffe HV, Goldhaber SZ. Upper-extremity deep vein thrombosis. *Circulation* 2002; 106(14):1874-1880.
2. Weissleder H, Weissleder R. Lymphedema: evaluation of qualitative and quantitative lymphoscintigraphy in 238 patients. *Radiology* 1988; 167(3):729-735.
3. Abdullah BJ, Mohammad N, Sangkar JV, et al. Incidence of upper limb venous thrombosis associated with peripherally inserted central catheters (PICC). *Br J Radiol* 2005; 78(931):596-600.
4. Baarslag HJ, Koopman MM, Reekers JA, van Beek EJ. Diagnosis and management of deep vein thrombosis of the upper extremity: a review. *Eur Radiol* 2004; 14(7):1263-1274.
5. Prandoni P, Polistena P, Bernardi E, et al. Upper-extremity deep vein thrombosis. Risk factors, diagnosis, and complications. *Arch Intern Med* 1997; 157(1):57-62.
6. Schmittling ZC, McLafferty RB, Bohannon WT, Ramsey DE, Hodgson KJ. Characterization and probability of upper extremity deep venous thrombosis. *Ann Vasc Surg* 2004; 18(5):552-557.
7. Spencer FA, Emery C, Lessard D, Goldberg RJ. Upper extremity deep vein thrombosis: a community-based perspective. *Am J Med* 2007; 120(8):678-684.
8. Baarslag HJ, van Beek EJ, Koopman MM, Reekers JA. Prospective study of color duplex ultrasonography compared with contrast venography in patients suspected of having deep venous thrombosis of the upper extremities. *Ann Intern Med* 2002; 136(12):865-872.
9. Shebel ND, Marin A. Effort thrombosis (Paget-Schroetter syndrome) in active young adults: current concepts in diagnosis and treatment. *J Vasc Nurs* 2006; 24(4):116-126.
10. Knudson GJ, Wiedmeyer DA, Erickson SJ, et al. Color Doppler sonographic imaging in the assessment of upper-extremity deep venous thrombosis. *AJR* 1990; 154(2):399-403.
11. Mustafa S, Stein PD, Patel KC, Otten TR, Holmes R, Silbergleit A. Upper extremity deep venous thrombosis. *Chest* 2003; 123(6):1953-1956.
12. Patel MC, Berman LH, Moss HA, McPherson SJ. Subclavian and internal jugular veins at Doppler US: abnormal cardiac pulsatility and respiratory phasicity as a predictor of complete central occlusion. *Radiology* 1999; 211(2):579-583.
13. Ong B, Gibbs H, Catchpole I, Hetherington R, Harper J. Peripherally inserted central catheters and upper extremity deep vein thrombosis. *Australas Radiol* 2006; 50(5):451-454.

14. Agarwal AK, Patel BM, Haddad NJ. Central vein stenosis: a nephrologist's perspective. *Semin Dial* 2007; 20(1):53-62.
15. Lam EY, Giswold ME, Moneta GL. Venous and Lymphatic Disease. In: Brunicaardi FC, Andersen DK, Billiar TR, et al., eds. *Schwartz's Principles of Surgery*. 8th ed: McGraw-Hill; 2005.
16. Hingorani AP, Ascher E, Markevich N, et al. Prospective evaluation of combined upper and lower extremity DVT. *Vasc Endovascular Surg* 2006; 40(2):131-134.
17. Constans J, Salmi LR, Sevestre-Pietri MA, et al. A clinical prediction score for upper extremity deep venous thrombosis. *Thromb Haemost* 2008; 99(1):202-207.
18. Merminod T, Pellicciotta S, Bounameaux H. Limited usefulness of D-dimer in suspected deep vein thrombosis of the upper extremities. *Blood Coagul Fibrinolysis* 2006; 17(3):225-226.
19. Di Nisio M, Van Sluis GL, Bossuyt PM, Buller HR, Porreca E, Rutjes AW. Accuracy of diagnostic tests for clinically suspected upper extremity deep vein thrombosis: a systematic review. *J Thromb Haemost* 2010; 8(4):684-692.
20. Sharif-Kashani B, Behzadnia N, Shahabi P, Sadr M. Screening for deep vein thrombosis in asymptomatic high-risk patients: a comparison between digital photoplethysmography and venous ultrasonography. *Angiology* 2009; 60(3):301-307.
21. Do B, Mari C, Biswal S, Kalinyak J, Quon A, Gambhir SS. Diagnosis of aseptic deep venous thrombosis of the upper extremity in a cancer patient using fluorine-18 fluorodeoxyglucose positron emission tomography/computerized tomography (FDG PET/CT). *Ann Nucl Med* 2006; 20(2):151-155.
22. Gloviczki P, Calcagno D, Schirger A, et al. Noninvasive evaluation of the swollen extremity: experiences with 190 lymphoscintigraphic examinations. *J Vasc Surg* 1989; 9(5):683-689; discussion 690.
23. Wang YF, Cherng SC, Chiu JS, Su YC, Sheu YT. Application of upper extremity radionuclide venography as a diagnostic approach for Port-A catheter thrombosis. *J Chin Med Assoc* 2006; 69(8):358-363.
24. Baxter GM, Kincaid W, Jeffrey RF, Millar GM, Porteous C, Morley P. Comparison of colour Doppler ultrasound with venography in the diagnosis of axillary and subclavian vein thrombosis. *Br J Radiol* 1991; 64(765):777-781.
25. Koksoy C, Kuzu A, Kutlay J, Erden I, Ozcan H, Ergin K. The diagnostic value of colour Doppler ultrasound in central venous catheter related thrombosis. *Clin Radiol* 1995; 50(10):687-689.
26. Weissleder R, Elizondo G, Stark DD. Sonographic diagnosis of subclavian and internal jugular vein thrombosis. *J Ultrasound Med* 1987; 6(10):577-587.
27. Chin EE, Zimmerman PT, Grant EG. Sonographic evaluation of upper extremity deep venous thrombosis. *J Ultrasound Med* 2005; 24(6):829-838; quiz 839-840.
28. Haire WD, Lynch TG, Lund GB, Lieberman RP, Edney JA. Limitations of magnetic resonance imaging and ultrasound-directed (duplex) scanning in the diagnosis of subclavian vein thrombosis. *J Vasc Surg* 1991; 13(3):391-397.
29. Svensson WE, Mortimer PS, Tohno E, Cosgrove DO. Colour Doppler demonstrates venous flow abnormalities in breast cancer patients with chronic arm swelling. *Eur J Cancer* 1994; 30A(5):657-660.
30. Weber TM, Lockhart ME, Robbin ML. Upper extremity venous Doppler ultrasound. *Radiol Clin North Am* 2007; 45(3):513-524.
31. Grassi CJ, Polak JF. Axillary and subclavian venous thrombosis: follow-up evaluation with color Doppler flow US and venography. *Radiology* 1990; 175(3):651-654.
32. Gaitini D, Beck-Razi N, Haim N, Brenner B. Prevalence of upper extremity deep venous thrombosis diagnosed by color Doppler duplex sonography in cancer patients with central venous catheters. *J Ultrasound Med* 2006; 25(10):1297-1303.
33. Haire WD, Lynch TG, Lieberman RP, Lund GB, Edney JA. Utility of duplex ultrasound in the diagnosis of asymptomatic catheter-induced subclavian vein thrombosis. *J Ultrasound Med* 1991; 10(9):493-496.
34. Ho VB, Corse WR, Hood MD, Rowedder AM. Magnetic resonance angiography of the thoracic vessels *Magnetic Resonance Imaging Clinics of North America* 2004; 12(4):727-747
35. Hansen ME, Spritzer CE, Sostman HD. Assessing the patency of mediastinal and thoracic inlet veins: value of MR imaging. *AJR* 1990; 155(6):1177-1182.
36. Blume U, Orbell J, Waltham M, Smith A, Razavi R, Schaeffter T. 3D T(1)-mapping for the characterization of deep vein thrombosis. *MAGMA* 2009; 22(6):375-383.
37. Baarslag HJ, Van Beek EJ, Reekers JA. Magnetic resonance venography in consecutive patients with suspected deep vein thrombosis of the upper extremity: initial experience. *Acta Radiol* 2004; 45(1):38-43.
38. Finn JP, Zisk JH, Edelman RR, et al. Central venous occlusion: MR angiography. *Radiology* 1993; 187(1):245-251.
39. Vogt FM, Herborn CU, Goyen M. MR venography. *Magn Reson Imaging Clin N Am* 2005; 13(1):113-129, vi.
40. Spritzer CE. Progress in MR imaging of the venous system. *Perspect Vasc Surg Endovasc Ther* 2009; 21(2):105-116.
41. Cantwell CP, Craddock A, Bruzzi J, Fitzpatrick P, Eustace S, Murray JG. MR venography with true fast imaging with steady-state precession for suspected lower-limb deep vein thrombosis. *J Vasc Interv Radiol* 2006; 17(11 Pt 1):1763-1769.
42. Miyazaki M, Sugiura S, Tateishi F, Wada H, Kassai Y, Abe H. Non-contrast-enhanced MR angiography using 3D ECG-synchronized half-Fourier fast spin echo. *J Magn Reson Imaging* 2000; 12(5):776-783.
43. Pedrosa I, Morrin M, Oleaga L, Baptista J, Rofsky NM. Is true FISP imaging reliable in the evaluation of venous thrombosis? *AJR* 2005; 185(6):1632-1640.
44. Denson K, Morgan D, Cunningham R, et al. Incidence of venous thromboembolism in patients with traumatic brain injury. *Am J Surg* 2007; 193(3):380-383; discussion 383-384.
45. Tanju S, Sancak T, Dusunceli E, Yagmurlu B, Erden I, Sanlidilek U. Direct contrast-enhanced 3D MR venography evaluation of upper extremity deep venous system. *Diagn Interv Radiol* 2006; 12(2):74-79.
46. Vymazal J, Spuentrup E, Cardenas-Molina G, et al. Thrombus imaging with fibrin-specific gadolinium-based MR contrast agent EP-2104R: results of a phase II clinical study of feasibility. *Invest Radiol* 2009; 44(11):697-704.
47. Kim CY, Mirza RA, Bryant JA, et al. Central veins of the chest: evaluation with time-resolved MR angiography. *Radiology* 2008; 247(2):558-566.
48. Ruehm S KK, Bosk S, et al. Thromboembolic disease: Assessment with whole body MR venography *Academic Radiology* 2005; 12(5, Supplement 1):S63.
49. Nael K, Krishnam M, Ruehm SG, Michaely HJ, Laub G, Finn JP. Time-resolved MR angiography in the evaluation of central thoracic venous occlusive disease. *AJR* 2009; 192(6):1731-1738.
50. Sampson FC, Goodacre SW, Thomas SM, van Beek EJ. The accuracy of MRI in diagnosis of suspected deep vein thrombosis: systematic review and meta-analysis. *Eur Radiol* 2007; 17(1):175-181.
51. Panzironi G, Rainaldi R, Ricci F, Casale A, De Vargas Macciucca M. Gray-scale and color Doppler findings in bilateral internal jugular vein thrombosis caused by anaplastic carcinoma of the thyroid. *J Clin Ultrasound* 2003; 31(2):111-115.
52. Stam J. Thrombosis of the cerebral veins and sinuses. *N Engl J Med* 2005; 352(17):1791-1798.
53. Kim HC, Chung JW, Yoon CJ, et al. Collateral pathways in thoracic central venous obstruction: three-dimensional display using direct spiral computed tomography venography. *J Comput Assist Tomogr* 2004; 28(1):24-33.
54. Sabharwal R, Boshell D, Vladica P. Multidetector spiral CT venography in the diagnosis of upper extremity deep venous thrombosis. *Australas Radiol* 2007; 51 Suppl:B253-256.
55. Kim H, Chung JW, Park JH, et al. Role of CT venography in the diagnosis and treatment of benign thoracic central venous obstruction. *Korean J Radiol* 2003; 4(3):146-152.
56. Arrive L, Crema MD, Lewin M, et al. Computed tomography features of acute thrombosis of central veins with perivenous inflammatory changes. *J Comput Assist Tomogr* 2007; 31(6):931-935.
57. New CT Protocol Yields Improved Venous Images *RSNA News* 2008; 18(1):6-7.
58. American College of Radiology. *Manual on Contrast Media*. Available at: [http://www.acr.org/SecondaryMainMenuCategories/quality\\_safety/contrast\\_manual.aspx](http://www.acr.org/SecondaryMainMenuCategories/quality_safety/contrast_manual.aspx).

The ACR Committee on Appropriateness Criteria and its expert panels have developed criteria for determining appropriate imaging examinations for diagnosis and treatment of specified medical condition(s). These criteria are intended to guide radiologists, radiation oncologists and referring physicians in making decisions regarding radiologic imaging and treatment. Generally, the complexity and severity of a patient's clinical condition should dictate the selection of appropriate imaging procedures or treatments. Only those examinations generally used for evaluation of the patient's condition are ranked. Other imaging studies necessary to evaluate other co-existent diseases or other medical consequences of this condition are not considered in this document. The availability of equipment or personnel may influence the selection of appropriate imaging procedures or treatments. Imaging techniques classified as investigational by the FDA have not been considered in developing these criteria; however, study of new equipment and applications should be encouraged. The ultimate decision regarding the appropriateness of any specific radiologic examination or treatment must be made by the referring physician and radiologist in light of all the circumstances presented in an individual examination.